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# International Cooperation in NASA Physical Sciences Research: Presentation to the Research Subcommittee

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# International Cooperation: NASA Physical Sciences Research

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- **Multilateral Engagement: International Microgravity Strategic Planning Group (IMSPG)**
  - Coordinate the development and use of ISS research among microgravity research programs in areas of common interest to maximize the productivity of microgravity research internationally.
  - Meets once a year on the margins of the annual meeting of the American Society for Gravitational and Space-Research
  - Members: ASI, CNES, CSA, ESA, DLR, JAXA, NASA and Roscosmos
  - Priority Areas for International Coordination Include:
    - All disciplines within Physical Sciences
    - Sharing facilities, experiment-specific hardware, data, etc.



# International Cooperation: NASA Physical Sciences Research

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- **Bilateral Engagement:** NASA works directly with other space agencies or research institutions - especially the ISS partner agencies (examples):
  - **ESA:** Collaborative research in the ESA Material Science Laboratory (MSL) furnaces using ESA-developed cartridges and supporting development of NASA cartridges, Electro Magnetic Levitation (EML) facility and Microwave Ground link stations for the Atomic Clock Ensemble in Space Experiment. (common and unilateral objectives)
  - **ASI:** Collaboration to study Biofuels using the NASA Combustion Integrated Rack
  - **CNES:** Joint use of a CNES DECLIC hardware for joint investigations in fluid physics and/or solidification of transparent materials.
  - **JAXA:** Cooperation on the combustion of fuel droplets using NASA's Combustion Integrated Rack (CIR) and JAXA's Group Combustion Experiment Module (GCEM) hardware to perform experiments (common and unilateral objectives).
  - **Russia:** OASIS – Scientists' protocol and ISS Program protocol – study the unique behavior of liquid crystals in microgravity using the NASA Microgravity Sciences Glovebox



# Benefits of International Cooperation on ISS Research

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- The ISS laboratory has reached a mature configuration including many unique research facilities provided by each International Partner.
- To maximize the utilization of these facilities, the partners are pursuing cooperative arrangements where partners perform investigations in each other's facilities and utilize each others on-orbit (and ground) resources.
- Benefits:
  - Allows access to more researchers from more countries
  - Fosters cooperative research objectives between partners
  - Allows complementary research to be performed in multiple facilities
  - Facilitates wide distribution of research data
  - Avoids duplication of facilities/capabilities in the severely limited volume of the ISS
  - Reduces crew training and operations planning by re-using existing facilities/capabilities
  - Reduces overall cost of research
  - Maximizes the return on investment for each facility



# SLPS Gravity-Dependent Physical Sciences Research

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## Biophysics

- Biological macromolecules
- Biomaterials
- Biological physics
- Fluids for Biology

## Combustion Science

- Spacecraft fire safety
- Droplets
- Gaseous – Premixed and Non-Premixed
- Solid Fuels
- Supercritical reacting fluids

## Fluid Physics

- Adiabatic two-phase flow
- Boiling, Condensation
- Capillary Flow
- Interfacial phenomena
- Cryogenics

## Materials Science

- Metals
- Semiconductors
- Polymers
- Glasses, Ceramics
- Granular Materials
- Composites
- Organics

## Fundamental Physics

- Space Optical/Atomic Clocks
- Quantum test of Equivalence Principle
- Cold atom physics
- Critical point phenomena
- Dusty plasmas

## Complex Fluids

- Colloids
- Liquid crystals
- Foams
- Gels
- Granular flows





# ISS Facilities for Physical Sciences Research



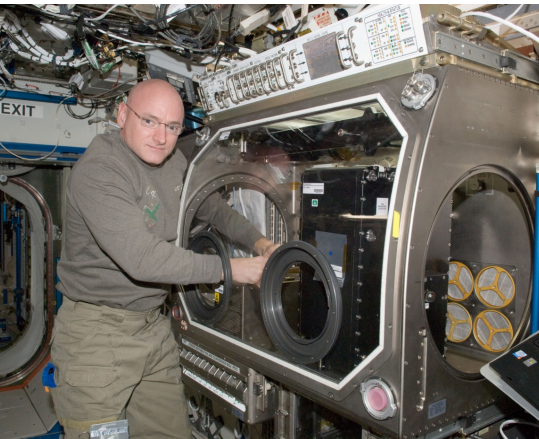
*Astronaut Mike Fincke completing install of the CIR/MDCA insert prior to CIR activation in January 2009.*



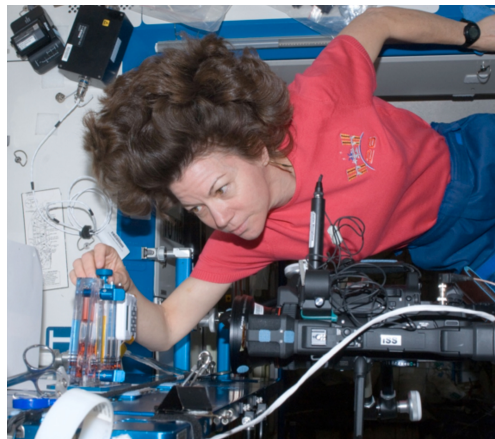
*Astronaut Frank DeWinne completing installation in the MSRR prior to on-orbit commissioning October 2009*



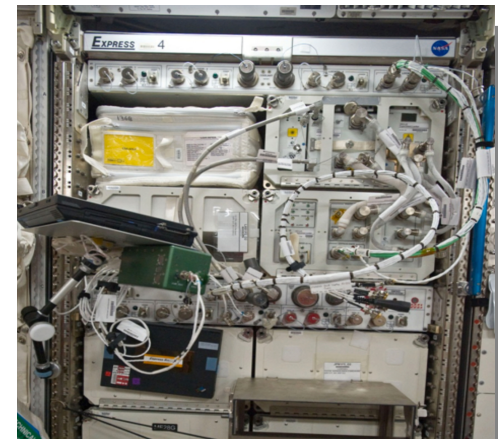
*Astronaut Paolo Nespoli operating the ACE experiment in the FIR/LMM*



*Increment 26 commander Scott Kelly installing CCF in the Microgravity Science Glovebox on ISS*



*Astronaut Cady Coleman operating the CFE experiment in Maintenance Work Area on the ISS*



*DECLIC installed in an EXPRESS Rack on board ISS*



# NASA's International Cooperation in Physical Sciences on ISS



Theme	Acronym	Experiment	International Partners							
			ESA	JAXA	CSA	ROS COS MOS	CNES	DLR	ASI	KARI
Combustion Science	SOFIE	Solid FLAmability of Materials Experiment								
	BASS-2	Burning and Suppression of Solids								
	FLEX-2	Flame Extinguishment Experiment-2								
	FLEX-2J	Flame Extinguishment experiment- with JAXA		P						
	SCE	Solid Combustion Expt. - 2012 JAXA AO, Fujita,Olsen..(2015, MSPR)		S						
	GCE	Group Combustion Experiment -2D droplet array		S						
	FLEX-ICE	Flame Extinguishment experiment-Italian Combustion Experiment							P	
	ISFSS	Int'l Standard of Fire Safety in Space – 2012 JAXA AO, Fujita,Olsen,etal (2016,MSPR)		S						
	ACME	Advanced Combustion via Microgravity Experiments (Gaseous)								
	SCWO (planned)	Super Critical Water Oxidation	P				P			
	SCWM	Super Critical Salt Water Mixture Experiment					S			

Blue Print: Experiment Acronyms in Blue are Sponsored by non-NASA Agency

S: Sponsor, P: Participant



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# International Collaboration

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- International Collaboration for each Physical Sciences Discipline
  - Biophysics
  - Combustion Science
  - Complex Fluids
  - Fluid Physics
  - Fundamental Physics
  - Materials Science



# NASA's International Cooperation in Physical Sciences on ISS



Theme	Acronym	Experiment	International Partners							
			ESA	JAXA	CSA	ROS COS MOS	CNES	DLR	ASI	KARI
Biophysics	PROTEIN	Protein Nucleation and Growth Kinetics Experiment (Vekilov)	S							
	Nano Step-2	Solution Crystallization Observation Facility, (SCOF), Suzuki, (Vekilov)		S						
	Delucas	Effect of Macromolecular Transport on Protein Crystallization						P		
	Vekilov	Solution Convection and Nucleation Precursors in Protein Crystallization								
	Snell	Growth Rate Dispersion of Biological Crystal Samples								
	Hirsa	Amyloid Fibril Formation in Microgravity								

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	FLEX-2J	Flame Extinguishment experiment- with JAXA		P						
	SCE	Solid Combustion Expt. - 2012 JAXA AO, Fujita,Olsen..(2015, MSPR)		S						
	GCE	Group Combustion Experiment -2D droplet array		S						
	FLEX-ICE	Flame Extinguishment experiment-Italian Combustion Experiment							P	
	ISFSS	Int'l Standard of Fire Safety in Space – 2012 JAXA AO, Fujita,Olsen,etal (2016,MSPR)		S						
	ACME	Advanced Combustion via Microgravity Experiments (Gaseous)								
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Complex Fluids	ACE	Advanced Colloids Experiment	P							P
	COLLOID	Colloidal Solids Experiment	S							
	PASTA-LIFT	PARTicle STAbilized Emulsions and Foams–Liquid Film Tensiometer	S							
	Soft Matter Dynamics (formerly FOAM-C)	Foam Optics and Mechanics–Coarsening	S							
	BCAT-C1	Binary Colloidal Alloy Test-Canada 1			S					
	InSPACE-3+	Investigating the Structure of Paramagnetic Aggregates From Colloidal Emulsions-3+								
	OASIS	Observation and Analysis of Smectic Islands in Space				P		P		
	VIPGRAN (COMPGRAN)	Compaction and Sound Transmission in Dense Granular Media	S							

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Fluid Physics	FBCE	Flow Boiling and Condensation Experiment								
	RUBI	Reference mUltiscale Boiling Investigation	S							
	MFHT	Multiphase Flow with Heat Transfer	S							
	ZBOT	Zero Boiloff Experiment								
	ZBOT-2	Zero Boiloff Experiment-2								
	CCF	Capillary Channel Flow						S		
	CFE-2	Capillary Flow Experiment-2								
	DOLFIN II	Dynamics of Liquid Film/ Complex Wall Interaction	S							
	CVB-2	Constrained Vapor Bubble-2								
	EHD	Electro-hydrodynamic flow								
	PBRE	Packed Bed Reactor Experiment								
	TPFSE	Two Phase Flow Separator Experiment								
	JEREMI	JAXA Marangoni Flow Experiment (Narayanan, Kamotani)		S						
	VIPIL-Faraday (Planned)	ESA Vibration in Liquids experiment, planning stages (Narayanan)	S							





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Fundamental Physics	ACES	Atomic Clock Ensemble in Space	S							
	SOC	Space Optical Clock	S							
	QTEST (planned)	Quantum Weak Equivalence Principle	P							
	CAL	Cold Atom Laboratory								
	PK-4	Plasma Kristall-4	S							
	PLASMALAB (planned)	Kinetic studies of strongly coupled systems: Interdisciplinary Research with Complex Plasmas	S							
	ALI-R	Alice Like Insert - reflight					S			

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Materials Science	CSLM-4	Coarsening of Dendritic Solid-Liquid Mixtures-4								
	DSI-R/SPADES	Spatiotemporal Evolution of Three-Dimensional Dendritic Array Structures					S			
	MICAST	Microstructure Formation in Castings	S							
	CETSOL	Columnar to Equiaxed Transition in Solidification Processing	S							
	SETA	Solidification along an Eutectic path in Ternary Alloys	S							
	METCOMP	Metastable solidification of Composites	S							
	SISSI	Silicon ISS Investigation	S							
	RDGS	Reduction of Defects in Germanium Silicon	S							
	CGTS	Crystal Growth of Ternary Compound Semiconductors	S							
	IE-ELF	Interfacial Energy- Electrostatic Levitator Furnace – 2012 JAXA AO, Watanabe, Heyers, et al. (2017, ELF)		S						
	GEDS	Gravitational Effects in Distortion in Sintering								
	FAMIS	Formation of Amorphous Metallics In Space								
	FOG	Formation of Gasarities								
	THERMOLAB	Thermophysical Properties of Liquid Metallic Alloys	S							
	ICOPROSOL	Thermophysical properties and solidification behavior of undercooled Ti-Zr-Ni liquids showing in icosahedral short-range order	S							
	PARSEC	Peritectic Alloy Rapid Solidification with Electromagnetic Convection	S							